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Kazi et al.

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(54) **DETERMINING WHEN TO INITIATE AN INTRA-DISTRIBUTED STORAGE UNIT REBUILD VS. AN INTER-DISTRIBUTED STORAGE UNIT REBUILD**

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G06F 11/00 (2006.01)
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CPC ***G06F 3/0604*** (2013.01); ***G06F 3/06*** (2013.01); ***G06F 3/067*** (2013.01); ***G06F 3/0611*** (2013.01);
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CPC G06F 11/1092; G06F 11/1076; G06F 3/0604; G06F 3/0622; G06F 3/0629; G06F 3/067; H04L 67/1097
See application file for complete search history.

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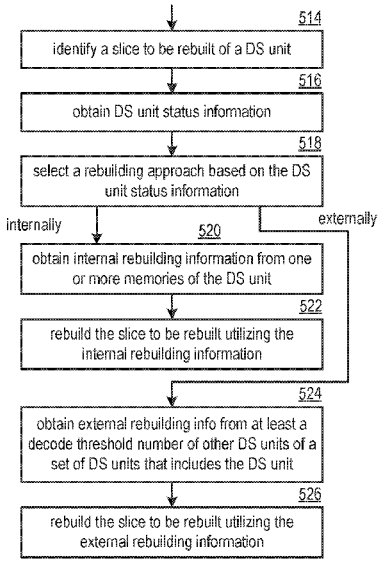
(57) **ABSTRACT**

A method for execution by one or more processing modules of one or more computing devices of a dispersed storage network (DSN), the method begins by identifying an encoded data slice to be rebuilt within a DS unit, obtaining DS unit status information, selecting a rebuilding approach based on the DS unit status information, the rebuilding approach including an internal approach or an external approach. The method continues by obtaining, upon selecting the internal approach, internal rebuilding information from one or more memories of the DS unit and rebuilding the encoded data slice to be rebuilt utilizing the internal rebuilding information. The method continues by obtaining, upon selecting the external approach, external rebuilding information from at least a decode threshold number of other DS units of a set of DS units that includes the DS unit and rebuilding the encoded data slice to be rebuilt utilizing the external rebuilding information.

18 Claims, 6 Drawing Sheets



Related U.S. Application Data

of application No. 15/011,807, filed on Feb. 1, 2016, now Pat. No. 9,766,810, which is a continuation of application No. 14/153,366, filed on Jan. 13, 2014, now Pat. No. 9,274,908.

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G06F 11/10	(2006.01)
G06F 11/30	(2006.01)

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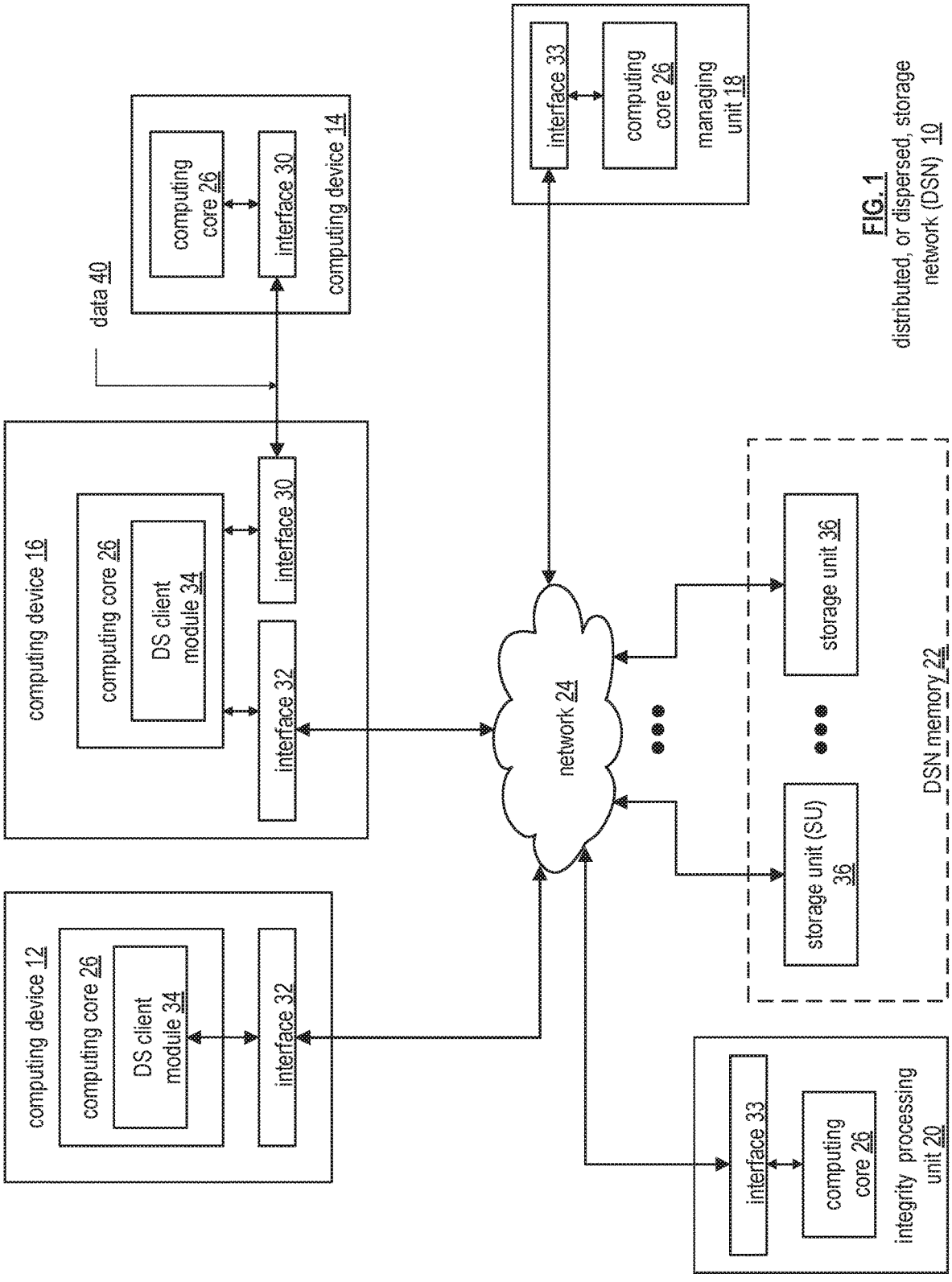

FIG. 1
distributed, or dispersed, storage network (DSN) 10

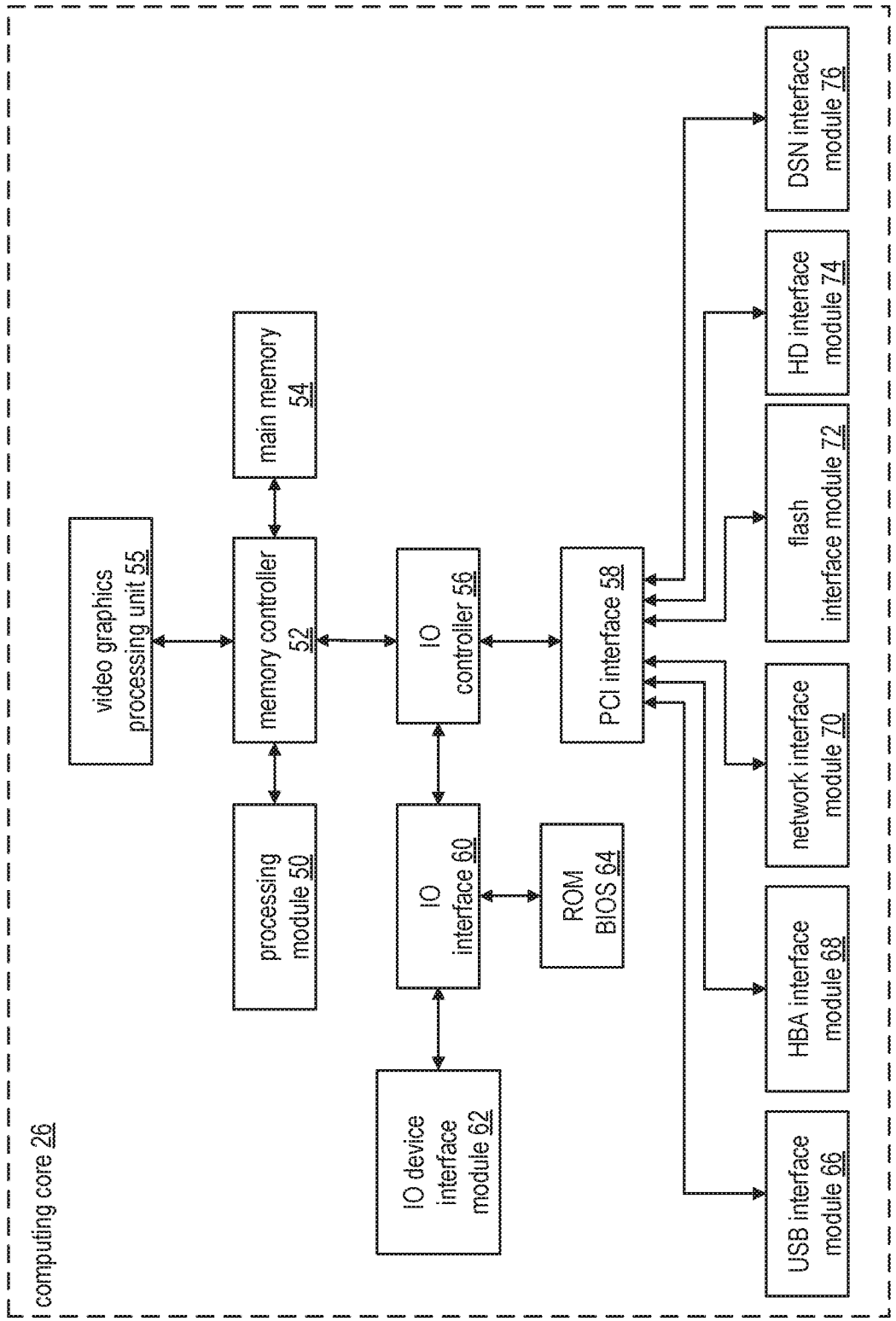
computing core 26
video graphics processing unit 55
main memory 54
memory controller 52
processing module 50
IO controller 56
IO interface 60
ROM BIOS 64
PCI interface 58
IO device interface module 62
USB interface module 66
HBA interface module 68
network interface module 70
flash interface module 72
HD interface module 74
DSN interface module 76

FIG. 2

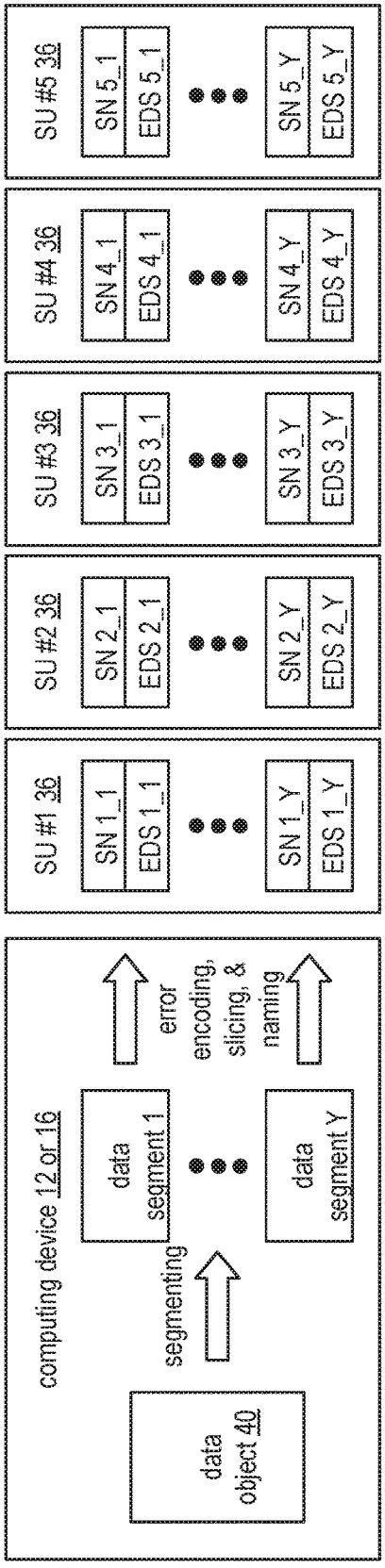

FIG. 3

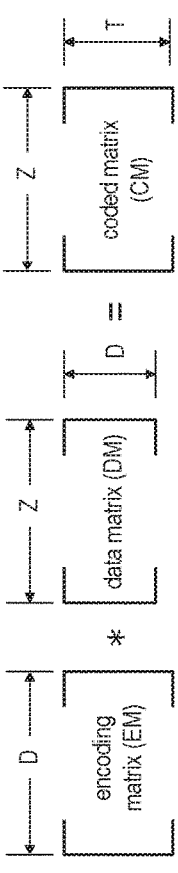

FIG. 4

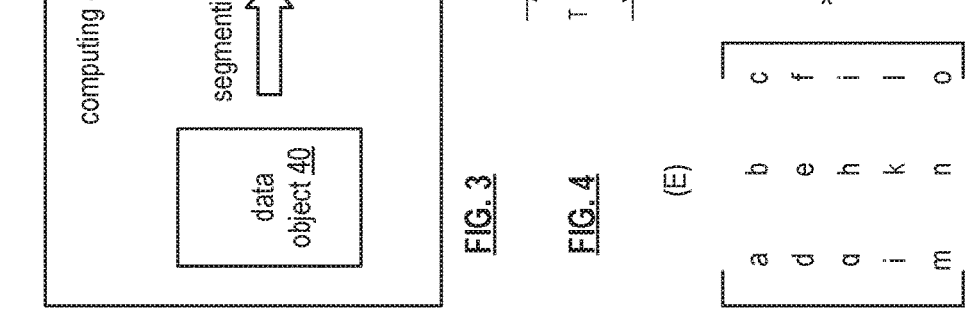

FIG. 5

FIG. 6

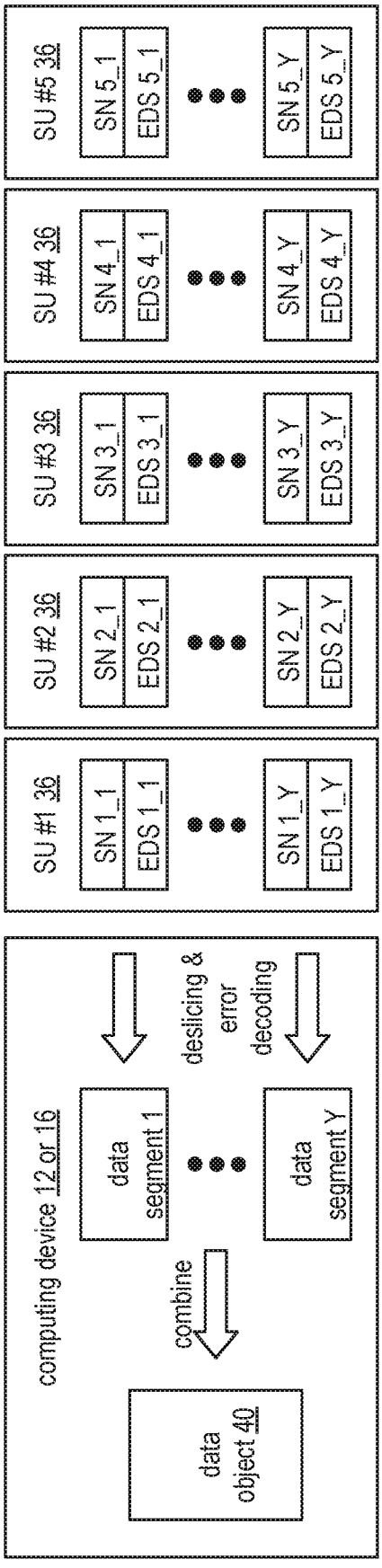
computing device 12 or 16
data object 40
combine
data segment 1
data segment Y
deslicing & error decoding
SU #1 36
SN 1_1
EDS 1_1
SN 1_Y
EDS 1_Y
SU #2 36
SN 2_1
EDS 2_1
SN 2_Y
EDS 2_Y
SU #3 36
SN 3_1
EDS 3_1
SN 3_Y
EDS 3_Y
SU #4 36
SN 4_1
EDS 4_1
SN 4_Y
EDS 4_Y
SU #5 36
SN 5_1
EDS 5_1
SN 5_Y
EDS 5_Y

FIG. 7

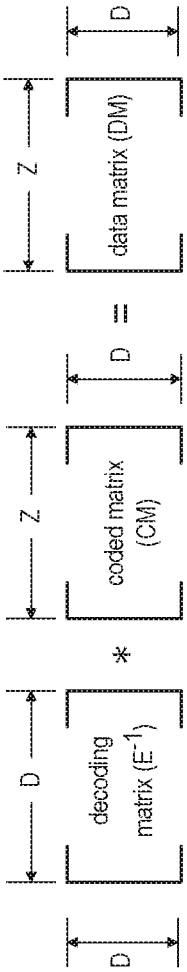
D
D
decoding matrix (E^{-1})
*
Z
Z
coded matrix (CM)
D
=
data matrix (DM)
D

FIG. 8

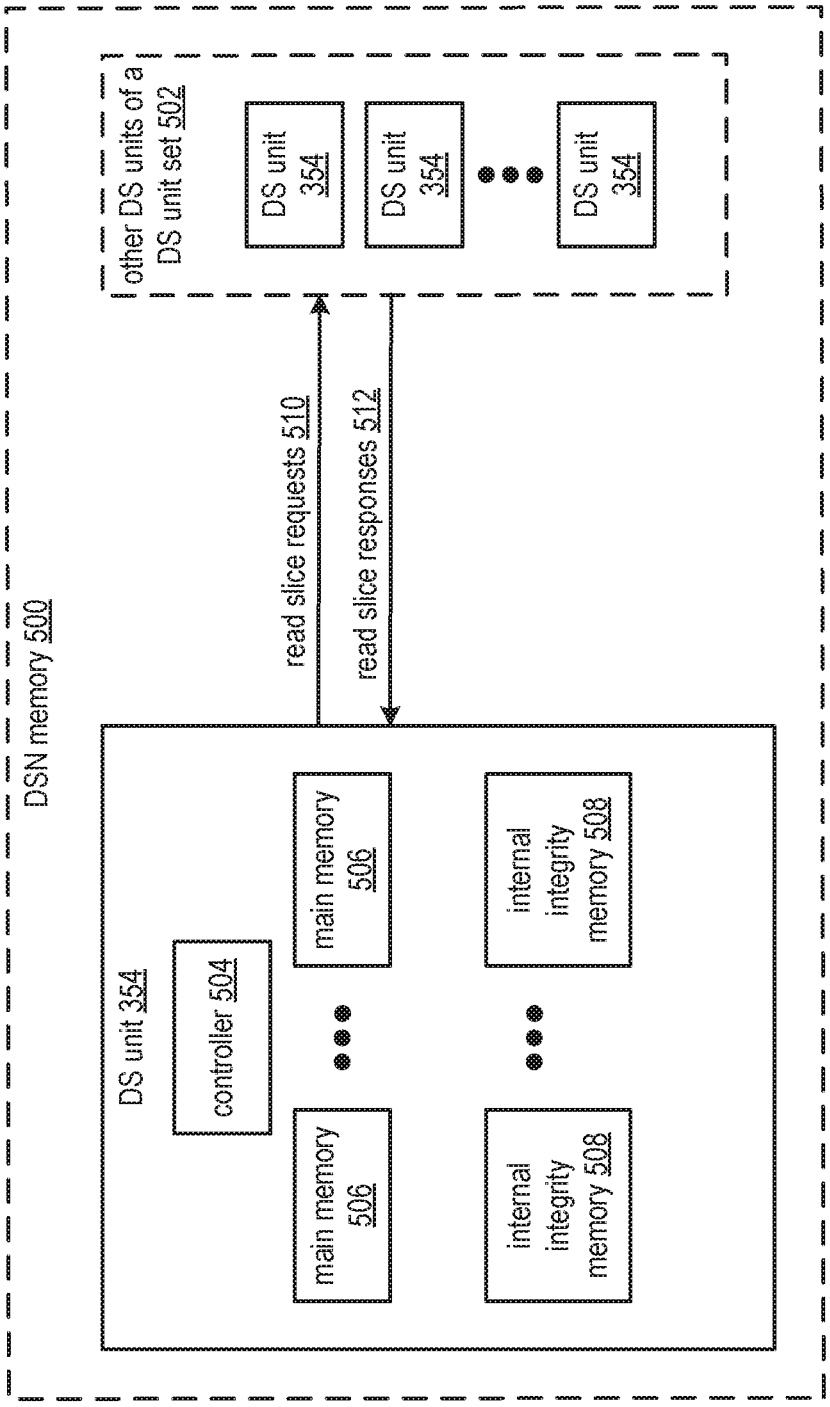
DSN memory 500
other DS units of a DS unit set 502
DS unit 354
DS unit 354
DS unit 354
read slice requests 510
read slice responses 512
DS unit 354
controller 504
main memory 506
main memory 506
internal integrity memory 508
internal integrity memory 508

FIG. 9

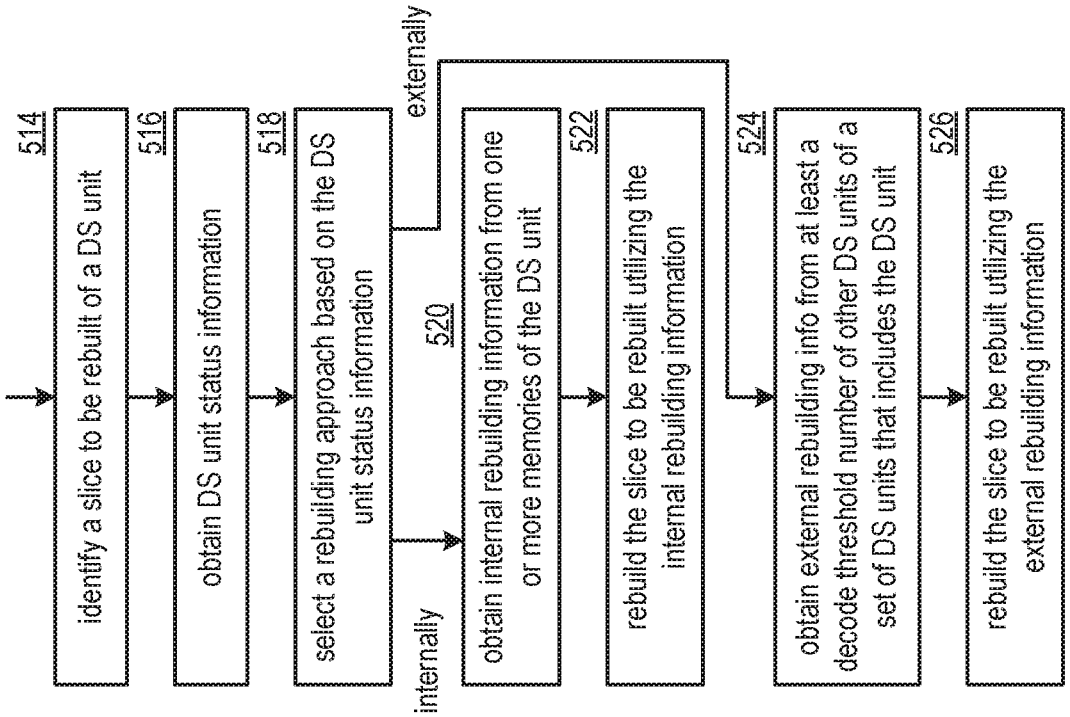
514
identify a slice to be rebuilt of a DS unit
516
obtain DS unit status information
518
select a rebuilding approach based on the DS unit status information
internally
externally
520
obtain internal rebuilding information from one or more memories of the DS unit
522
rebuild the slice to be rebuilt utilizing the internal rebuilding information
524
obtain external rebuilding info from at least a decode threshold number of other DS units of a set of DS units that includes the DS unit
526
rebuild the slice to be rebuilt utilizing the external rebuilding information

FIG. 9A

DETERMINING WHEN TO INITIATE AN INTRA-DISTRIBUTED STORAGE UNIT REBUILD VS. AN INTER-DISTRIBUTED STORAGE UNIT REBUILD

CROSS-REFERENCE TO RELATED APPLICATIONS

The present U.S. Utility Patent Application claims priority pursuant to 35 U.S.C. § 120, as a continuation-in-part (CIP) of U.S. Utility patent application Ser. No. 15/656,245, entitled "DETERMINING WHEN TO USE CONVERGENT ENCRYPTION," filed Jul. 21, 2017, which claims priority as a continuation-in-part of U.S. Utility application Ser. No. 15/011,807 entitled "RESOLVING WRITE CONFLICTS IN A DISPERSED STORAGE NETWORK" filed Feb. 1, 2016, issued as U.S. Pat. No. 9,766,810, on Sep. 19, 2017, which claims priority pursuant to 35 U.S.C. § 120 as a continuation of U.S. Utility application Ser. No. 14/153,366, entitled "RESOLVING WRITE CONFLICTS IN A DISPERSED STORAGE NETWORK", filed Jan. 13, 2014, issued as U.S. Pat. No. 9,274,908, on Mar. 1, 2016, which claims priority pursuant to 35 U.S.C. § 119(e) to U.S. Provisional Application No. 61/769,595, entitled "SECURELY STORING DATA WITHOUT DUPLICATION IN A DISPERSED STORAGE NETWORK", filed Feb. 26, 2013, all of which are hereby incorporated herein by reference in their entirety and made part of the present U.S. Utility Patent Application for all purposes.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable.

INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC

Not applicable.

BACKGROUND OF THE INVENTION

Technical Field of the Invention

This invention relates generally to computer networks and more particularly to dispersing error encoded data.

Description of Related Art

Computing devices are known to communicate data, process data, and/or store data. Such computing devices range from wireless smart phones, laptops, tablets, personal computers (PC), work stations, and video game devices, to data centers that support millions of web searches, stock trades, or on-line purchases every day. In general, a computing device includes a central processing unit (CPU), a memory system, user input/output interfaces, peripheral device interfaces, and an interconnecting bus structure.

As is further known, a computer may effectively extend its CPU by using "cloud computing" to perform one or more computing functions (e.g., a service, an application, an algorithm, an arithmetic logic function, etc.) on behalf of the computer. Further, for large services, applications, and/or functions, cloud computing may be performed by multiple cloud computing resources in a distributed manner to improve the response time for completion of the service, application, and/or function. For example, Hadoop is an open source software framework that supports distributed applications enabling application execution by thousands of computers.

In addition to cloud computing, a computer may use "cloud storage" as part of its memory system. As is known, cloud storage enables a user, via its computer, to store files, applications, etc. on an Internet storage system. The Internet storage system may include a RAID (redundant array of independent disks) system and/or a dispersed storage system that uses an error correction scheme to encode data for storage.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

FIG. **1** is a schematic block diagram of an embodiment of a dispersed or distributed storage network (DSN) in accordance with the present invention;

FIG. **2** is a schematic block diagram of an embodiment of a computing core in accordance with the present invention;

FIG. **3** is a schematic block diagram of an example of dispersed storage error encoding of data in accordance with the present invention;

FIG. **4** is a schematic block diagram of a generic example of an error encoding function in accordance with the present invention;

FIG. **5** is a schematic block diagram of a specific example of an error encoding function in accordance with the present invention;

FIG. **6** is a schematic block diagram of an example of a slice name of an encoded data slice (EDS) in accordance with the present invention;

FIG. **7** is a schematic block diagram of an example of dispersed storage error decoding of data in accordance with the present invention;

FIG. **8** is a schematic block diagram of a generic example of an error decoding function in accordance with the present invention;

FIG. **9** is a schematic block diagram of a dispersed storage network memory in accordance with the present invention; and

FIG. **9A** is a flowchart illustrating an example of rebuilding a slice to be rebuilt in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a schematic block diagram of an embodiment of a dispersed, or distributed, storage network (DSN) **10** that includes a plurality of computing devices **12-16**, a managing unit **18**, an integrity processing unit **20**, and a DSN memory **22**. The components of the DSN **10** are coupled to a network **24**, which may include one or more wireless and/or wire lined communication systems; one or more non-public intranet systems and/or public internet systems; and/or one or more local area networks (LAN) and/or wide area networks (WAN).

The DSN memory **22** includes a plurality of storage units **36** that may be located at geographically different sites (e.g., one in Chicago, one in Milwaukee, etc.), at a common site, or a combination thereof. For example, if the DSN memory **22** includes eight storage units **36**, each storage unit is located at a different site. As another example, if the DSN memory **22** includes eight storage units **36**, all eight storage units are located at the same site. As yet another example, if

the DSN memory **22** includes eight storage units **36**, a first pair of storage units are at a first common site, a second pair of storage units are at a second common site, a third pair of storage units are at a third common site, and a fourth pair of storage units are at a fourth common site. Note that a DSN memory **22** may include more or less than eight storage units **36**. Further note that each storage unit **36** includes a computing core (as shown in FIG. **2**, or components thereof) and a plurality of memory devices for storing dispersed error encoded data.

Each of the computing devices **12-16**, the managing unit **18**, and the integrity processing unit **20** include a computing core **26**, which includes network interfaces **30-33**. Computing devices **12-16** may each be a portable computing device and/or a fixed computing device. A portable computing device may be a social networking device, a gaming device, a cell phone, a smart phone, a digital assistant, a digital music player, a digital video player, a laptop computer, a handheld computer, a tablet, a video game controller, and/or any other portable device that includes a computing core. A fixed computing device may be a computer (PC), a computer server, a cable set-top box, a satellite receiver, a television set, a printer, a fax machine, home entertainment equipment, a video game console, and/or any type of home or office computing equipment. Note that each of the managing unit **18** and the integrity processing unit **20** may be separate computing devices, may be a common computing device, and/or may be integrated into one or more of the computing devices **12-16** and/or into one or more of the storage units **36**.

Each interface **30**, **32**, and **33** includes software and hardware to support one or more communication links via the network **24** indirectly and/or directly. For example, interface **30** supports a communication link (e.g., wired, wireless, direct, via a LAN, via the network **24**, etc.) between computing devices **14** and **16**. As another example, interface **32** supports communication links (e.g., a wired connection, a wireless connection, a LAN connection, and/or any other type of connection to/from the network **24**) between computing devices **12** & **16** and the DSN memory **22**. As yet another example, interface **33** supports a communication link for each of the managing unit **18** and the integrity processing unit **20** to the network **24**.

Computing devices **12** and **16** include a dispersed storage (DS) client module **34**, which enables the computing device to dispersed storage error encode and decode data as subsequently described with reference to one or more of FIGS. **3-9**A. In this example embodiment, computing device **16** functions as a dispersed storage processing agent for computing device **14**. In this role, computing device **16** dispersed storage error encodes and decodes data on behalf of computing device **14**. With the use of dispersed storage error encoding and decoding, the DSN **10** is tolerant of a significant number of storage unit failures (the number of failures is based on parameters of the dispersed storage error encoding function) without loss of data and without the need for a redundant or backup copies of the data. Further, the DSN **10** stores data for an indefinite period of time without data loss and in a secure manner (e.g., the system is very resistant to unauthorized attempts at accessing the data).

In operation, the managing unit **18** performs DS management services. For example, the managing unit **18** establishes distributed data storage parameters (e.g., vault creation, distributed storage parameters, security parameters, billing information, user profile information, etc.) for computing devices **12-14** individually or as part of a group of user devices. As a specific example, the managing unit **18** coordinates creation of a vault (e.g., a virtual memory block associated with a portion of an overall namespace of the DSN) within the DSTN memory **22** for a user device, a group of devices, or for public access and establishes per vault dispersed storage (DS) error encoding parameters for a vault. The managing unit **18** facilitates storage of DS error encoding parameters for each vault by updating registry information of the DSN **10**, where the registry information may be stored in the DSN memory **22**, a computing device **12-16**, the managing unit **18**, and/or the integrity processing unit **20**.

The DSN managing unit **18** creates and stores user profile information (e.g., an access control list (ACL)) in local memory and/or within memory of the DSN memory **22**. The user profile information includes authentication information, permissions, and/or the security parameters. The security parameters may include encryption/decryption scheme, one or more encryption keys, key generation scheme, and/or data encoding/decoding scheme.

The DSN managing unit **18** creates billing information for a particular user, a user group, a vault access, public vault access, etc. For instance, the DSTN managing unit **18** tracks the number of times a user accesses a non-public vault and/or public vaults, which can be used to generate per-access billing information. In another instance, the DSTN managing unit **18** tracks the amount of data stored and/or retrieved by a user device and/or a user group, which can be used to generate per-data-amount billing information.

As another example, the managing unit **18** performs network operations, network administration, and/or network maintenance. Network operations includes authenticating user data allocation requests (e.g., read and/or write requests), managing creation of vaults, establishing authentication credentials for user devices, adding/deleting components (e.g., user devices, storage units, and/or computing devices with a DS client module **34**) to/from the DSN **10**, and/or establishing authentication credentials for the storage units **36**. Network administration includes monitoring devices and/or units for failures, maintaining vault information, determining device and/or unit activation status, determining device and/or unit loading, and/or determining any other system level operation that affects the performance level of the DSN **10**. Network maintenance includes facilitating replacing, upgrading, repairing, and/or expanding a device and/or unit of the DSN **10**.

The integrity processing unit **20** performs rebuilding of 'bad' or missing encoded data slices. At a high level, the integrity processing unit **20** performs rebuilding by periodically attempting to retrieve/list encoded data slices, and/or slice names of the encoded data slices, from the DSN memory **22**. For retrieved encoded slices, they are checked for errors due to data corruption, outdated version, etc. If a slice includes an error, it is flagged as a 'bad' slice. For encoded data slices that were not received and/or not listed, they are flagged as missing slices. Bad and/or missing slices are subsequently rebuilt using other retrieved encoded data slices that are deemed to be good slices to produce rebuilt slices. The rebuilt slices are stored in the DSTN memory **22**.

FIG. **2** is a schematic block diagram of an embodiment of a computing core **26** that includes a processing module **50**, a memory controller **52**, main memory **54**, a video graphics processing unit **55**, an input/output (IO) controller **56**, a peripheral component interconnect (PCI) interface **58**, an IO interface module **60**, at least one IO device interface module **62**, a read only memory (ROM) basic input output system (BIOS) **64**, and one or more memory interface modules. The one or more memory interface module(s) includes one or

more of a universal serial bus (USB) interface module **66**, a host bus adapter (HBA) interface module **68**, a network interface module **70**, a flash interface module **72**, a hard drive interface module **74**, and a DSN interface module **76**.

The DSN interface module **76** functions to mimic a conventional operating system (OS) file system interface (e.g., network file system (NFS), flash file system (FFS), disk file system (DFS), file transfer protocol (FTP), web-based distributed authoring and versioning (WebDAV), etc.) and/or a block memory interface (e.g., small computer system interface (SCSI), internet small computer system interface (iSCSI), etc.). The DSN interface module **76** and/or the network interface module **70** may function as one or more of the interface **30-33** of FIG. **1**. Note that the IO device interface module **62** and/or the memory interface modules **66-76** may be collectively or individually referred to as IO ports.

FIG. **3** is a schematic block diagram of an example of dispersed storage error encoding of data. When a computing device **12** or **16** has data to store it disperse storage error encodes the data in accordance with a dispersed storage error encoding process based on dispersed storage error encoding parameters. The dispersed storage error encoding parameters include an encoding function (e.g., information dispersal algorithm, Reed-Solomon, Cauchy Reed-Solomon, systematic encoding, non-systematic encoding, on-line codes, etc.), a data segmenting protocol (e.g., data segment size, fixed, variable, etc.), and per data segment encoding values. The per data segment encoding values include a total, or pillar width, number (T) of encoded data slices per encoding of a data segment i.e., in a set of encoded data slices); a decode threshold number (D) of encoded data slices of a set of encoded data slices that are needed to recover the data segment; a read threshold number (R) of encoded data slices to indicate a number of encoded data slices per set to be read from storage for decoding of the data segment; and/or a write threshold number (W) to indicate a number of encoded data slices per set that must be accurately stored before the encoded data segment is deemed to have been properly stored. The dispersed storage error encoding parameters may further include slicing information (e.g., the number of encoded data slices that will be created for each data segment) and/or slice security information (e.g., per encoded data slice encryption, compression, integrity checksum, etc.).

In the present example, Cauchy Reed-Solomon has been selected as the encoding function (a generic example is shown in FIG. **4** and a specific example is shown in FIG. **5**); the data segmenting protocol is to divide the data object into fixed sized data segments; and the per data segment encoding values include: a pillar width of 5, a decode threshold of 3, a read threshold of 4, and a write threshold of 4. In accordance with the data segmenting protocol, the computing device **12** or **16** divides the data (e.g., a file (e.g., text, video, audio, etc.), a data object, or other data arrangement) into a plurality of fixed sized data segments (e.g., 1 through Y of a fixed size in range of Kilo-bytes to Tera-bytes or more). The number of data segments created is dependent of the size of the data and the data segmenting protocol.

The computing device **12** or **16** then disperse storage error encodes a data segment using the selected encoding function (e.g., Cauchy Reed-Solomon) to produce a set of encoded data slices. FIG. **4** illustrates a generic Cauchy Reed-Solomon encoding function, which includes an encoding matrix (EM), a data matrix (DM), and a coded matrix (CM). The size of the encoding matrix (EM) is dependent on the pillar width number (T) and the decode threshold number (D) of selected per data segment encoding values. To produce the data matrix (DM), the data segment is divided into a plurality of data blocks and the data blocks are arranged into D number of rows with Z data blocks per row. Note that Z is a function of the number of data blocks created from the data segment and the decode threshold number (D). The coded matrix is produced by matrix multiplying the data matrix by the encoding matrix.

FIG. **5** illustrates a specific example of Cauchy Reed-Solomon encoding with a pillar number (T) of five and decode threshold number of three. In this example, a first data segment is divided into twelve data blocks (D**1**-D**12**). The coded matrix includes five rows of coded data blocks, where the first row of X**11**-X**14** corresponds to a first encoded data slice (EDS **1_1**), the second row of X**21**-X**24** corresponds to a second encoded data slice (EDS **2_1**), the third row of X**31**-X**34** corresponds to a third encoded data slice (EDS **3_1**), the fourth row of X**41**-X**44** corresponds to a fourth encoded data slice (EDS **4_1**), and the fifth row of X**51**-X**54** corresponds to a fifth encoded data slice (EDS **5_1**). Note that the second number of the EDS designation corresponds to the data segment number.

Returning to the discussion of FIG. **3**, the computing device also creates a slice name (SN) for each encoded data slice (EDS) in the set of encoded data slices. A typical format for a slice name **60** is shown in FIG. **6**. As shown, the slice name (SN) **60** includes a pillar number of the encoded data slice (e.g., one of 1-T), a data segment number (e.g., one of 1-Y), a vault identifier (ID), a data object identifier (ID), and may further include revision level information of the encoded data slices. The slice name functions as, at least part of, a DSN address for the encoded data slice for storage and retrieval from the DSN memory **22**.

As a result of encoding, the computing device **12** or **16** produces a plurality of sets of encoded data slices, which are provided with their respective slice names to the storage units for storage. As shown, the first set of encoded data slices includes EDS **1_1** through EDS **5_1** and the first set of slice names includes SN **1_1** through SN **5_1** and the last set of encoded data slices includes EDS **1**_Y through EDS **5**_Y and the last set of slice names includes SN **1**_Y through SN **5**_Y.

FIG. **7** is a schematic block diagram of an example of dispersed storage error decoding of a data object that was dispersed storage error encoded and stored in the example of FIG. **4**. In this example, the computing device **12** or **16** retrieves from the storage units at least the decode threshold number of encoded data slices per data segment. As a specific example, the computing device retrieves a read threshold number of encoded data slices.

To recover a data segment from a decode threshold number of encoded data slices, the computing device uses a decoding function as shown in FIG. **8**. As shown, the decoding function is essentially an inverse of the encoding function of FIG. **4**. The coded matrix includes a decode threshold number of rows (e.g., three in this example) and the decoding matrix in an inversion of the encoding matrix that includes the corresponding rows of the coded matrix. For example, if the coded matrix includes rows **1**, **2**, and **4**, the encoding matrix is reduced to rows **1**, **2**, and **4**, and then inverted to produce the decoding matrix.

Within a DS unit, a set of memory devices may be arranged in a mode of striping with optional parity. This enables a greater overall throughput to access of slices within the DS unit as multiple disks each contribute a smaller proportion of the overall content. In addition, in the event of a drive failure, the drive may be rebuilt from the

additional parity information and the additional drives without having to contact other DS units. If there are multiple drive failures beyond the capacity for the RAID parity to recover, then an inter-DS unit rebuild must be initiated. When network communication is down, only an intra-DS unit rebuild is possible. In one embodiment, when both possibilities are available, a determination of whether to execute an intra- vs. an inter-ds unit rebuild is made. This determination may be made based on a performance requirement, a bandwidth cost, internal I/O (input/output) load of the device, available CPU resources, and other related factors. For example, if a rebalancing operation is occurring causing heavy internal memory device utilization, the DS unit may opt for an inter-DS unit rebuild as opposed to an intra-DS unit rebuild. If, on the other hand, the DS unit is on a WAN and bandwidth is expensive, it may tend to prefer an intra-DS unit rebuild.

FIG. **9** is a schematic block diagram of a dispersed storage network (DSN) memory **500** that includes a plurality of the dispersed storage (DS) units **354**. The plurality of DS units **354** includes at least one DS unit set that includes a DS unit **354** and other DS units **502** of the DS unit set. The DS unit **354** includes a controller **504**, a plurality of main memories **506**, and a plurality of internal integrity memories **508**. The DSN memory **500** functions to rebuild an encoded data slice to be rebuilt, where the encoded data slice to be rebuilt is associated with a main memory **506** of the plurality of main memories. Data is encoded using at least one of a dispersed storage error coding function or a redundant array of independent disks (RAID) coding function to produce rebuilding information, where recovery of the encoded data slice to be rebuilt is enabled by retrieving a threshold number of rebuilding elements of the rebuilding information. The rebuilding elements include one or more of parity information or other encoded data slices of a set of encoded data slices that includes the encoded data slice to be rebuilt. DSN memory **500** and DS units **354** can be implemented using DSN memory **22** and storage units **36**, respectively, as illustrated in FIG. **1**

In an example of operation, the controller **504** identifies the encoded data slice to be rebuilt. The identifying includes a variety of approaches. A first approach includes indicating that the encoded data slice to be rebuilt requires rebuilding when a calculated integrity value of the encoded data slice to be rebuilt compares unfavorably to a retrieved integrity value associated with the encoded data slice to be rebuilt, where the retrieved integrity value is retrieved from an associated internal integrity memory. A second approach includes receiving an error message that includes an identifier of the encoded data slice to be rebuilt. A third approach includes receiving a rebuilding request that includes the identifier of the encoded data slice to be rebuilt.

Having identified the encoded data slice to be rebuilt, the controller **504** selects a rebuilding approach as one of an internal approach or an external approach. The selecting may be based on one or more of network traffic level, a main memory availability indicator, an internal integrity memory availability indicator, a number of available other DS units of the DS unit set, a performance requirement, estimated network traffic costs, a controller loading level, available control resources, or an active rebalancing operation status. The internal approach is associated with utilizing rebuilding information from at least a threshold number of internal integrity memories of the plurality of internal integrity memories. The external approach is associated with utilizing rebuilding information from at least a threshold number of other DS units of the DS unit set. For example, the controller **504** selects the internal approach when estimated network traffic costs are greater than a cost threshold. As another example, the controller **504** selects the external approach when the controller loading level is greater than a loading level threshold.

When the selected rebuilding approach includes the internal approach, the controller **504** retrieves a threshold number of rebuilding elements from the threshold number of internal integrity memories **508**. For example, the controller **504** retrieves a threshold number of data blocks and/or parity blocks of a common data slice that includes the encoded data slice to be rebuilt when the RAID function is utilized. As another example, the controller **504** retrieves a threshold number of encoded data slices of the set of encoded data slices that includes the encoded data slice to be rebuilt from the threshold number of internal integrity memories **508** when the dispersed storage error coding function is utilized. The controller **504** decodes the threshold number of rebuilding elements to produce a rebuilt encoded data slice.

When the selected rebuilding approach includes the external approach, the controller **504** retrieves the threshold number of rebuilding elements from the threshold number of other DS units of the DS unit set **502**. For example, the controller **504** issues read slice requests **510** and receives read slice responses **512** to retrieve the threshold number of encoded data slices of the set of encoded data slices that includes the encoded data slice to be rebuilt from the threshold number of other DS units of the DS unit set when the dispersed storage error coding function is utilized. The controller decodes the threshold number of rebuilding elements to produce the rebuilt encoded data slice.

FIG. **9A** is a flowchart illustrating an example of rebuilding a slice to be rebuilt. The method begins at step **514** where a processing module (e.g., of a dispersed storage (DS) processing module) identifies a slice to be rebuilt associated with a DS unit. The identifying includes at least one of receiving an error message, comparing storage integrity information to calculated integrity information, or comparing a slice name list from the DS unit and from other DS units of a DS unit set that includes the DS unit. The method continues at step **516** where the processing module obtains DS unit status information. The DS unit status information includes one or more of a network traffic level, a number of available other DS units of the DS unit set, estimated network traffic costs, a loading level of the DS unit, available resources of the DS unit, or active operation types of the DS unit.

The method continues at step **518** where the processing module selects a rebuilding approach based on the DS unit status information. The rebuilding approach includes one of an internal approach and an external approach. The internal approach is associated with utilizing rebuilding information from one or more memories (e.g., a threshold number) of the DS unit. The external approach is associated with utilizing rebuilding information from at least a threshold number of other DS units of the DS unit set where data is encoded using a dispersed storage error coding function to produce a set of encoded data slices, including the encoded data slice to be rebuilt, that are stored in the DS unit set. The method branches to step **524** when the processing module selects the external approach. The method continues to step **520** when the processing module selects the internal approach.

The method continues at step **520** where the processing module obtains internal rebuilding information from one or more memories of the DS unit when the internal approach is selected. The internal rebuilding information includes at least one of a threshold number of encoded data slices of the

set of encoded data slices when the dispersed storage error coding function is utilized and a threshold number of data blocks and parity blocks when a redundant array of independent disks (RAID) function is utilized. For example, the processing module retrieves the threshold number of data blocks and parity blocks from a threshold number of memories of the DS unit when the RAID function is utilized. As another example, the processing module retrieves the threshold number of encoded data slices from the threshold number of memories of the DS unit when the dispersed storage error coding function is utilized. The dispersed storage error coding function and the RAID function may be utilized in accordance with a storage approach. The processing module may further determine the storage approach based on one or more of receiving the storage approach, a lookup, and selecting the storage approach based on storage requirements when initially storing data.

The method continues at step **522** where the processing module rebuilds the encoded data slice to be rebuilt utilizing the internal rebuilding information. For example, the processing module decodes the retrieved threshold number of encoded data slices using the dispersed storage error coding function to produce a rebuilt slice. As another example, the processing module utilizes the RAID function on the threshold number of data blocks and parity blocks to produce the rebuilt slice.

The method continues at step **524** where the processing module obtains external rebuilding information from at least a decode threshold number of other DS units of the set of DS units that includes the DS unit when the processing module selects the external approach. The obtaining includes issuing at least a decode threshold number of reads slice requests to the other DS units and receiving at least a decode threshold number of read slice responses. The method continues at step **526** where the processing module rebuilds the slice to be rebuilt utilizing the external rebuilding information. For example, the processing module decodes at least a decode threshold number of encoded data slices from the at least a decode threshold number of received read slice responses to produce the slice to be rebuilt.

The method described above in conjunction with the processing module can alternatively be performed by other modules of the dispersed storage network or by other computing devices. In addition, at least one memory section (e.g., a non-transitory computer readable storage medium) that stores operational instructions can, when executed by one or more processing modules of one or more computing devices of the dispersed storage network (DSN), cause the one or more computing devices to perform any or all of the method steps described above.

It is noted that terminologies as may be used herein such as bit stream, stream, signal sequence, etc. (or their equivalents) have been used interchangeably to describe digital information whose content corresponds to any of a number of desired types (e.g., data, video, speech, audio, etc. any of which may generally be referred to as 'data').

As may be used herein, the terms "substantially" and "approximately" provides an industry-accepted tolerance for its corresponding term and/or relativity between items. Such an industry-accepted tolerance ranges from less than one percent to fifty percent and corresponds to, but is not limited to, component values, integrated circuit process variations, temperature variations, rise and fall times, and/or thermal noise. Such relativity between items ranges from a difference of a few percent to magnitude differences. As may also be used herein, the term(s) "configured to", "operably coupled to", "coupled to", and/or "coupling" includes direct coupling between items and/or indirect coupling between items via an intervening item (e.g., an item includes, but is not limited to, a component, an element, a circuit, and/or a module) where, for an example of indirect coupling, the intervening item does not modify the information of a signal but may adjust its current level, voltage level, and/or power level. As may further be used herein, inferred coupling (i.e., where one element is coupled to another element by inference) includes direct and indirect coupling between two items in the same manner as "coupled to". As may even further be used herein, the term "configured to", "operable to", "coupled to", or "operably coupled to" indicates that an item includes one or more of power connections, input(s), output(s), etc., to perform, when activated, one or more its corresponding functions and may further include inferred coupling to one or more other items. As may still further be used herein, the term "associated with", includes direct and/or indirect coupling of separate items and/or one item being embedded within another item.

As may be used herein, the term "compares favorably", indicates that a comparison between two or more items, signals, etc., provides a desired relationship. For example, when the desired relationship is that signal **1** has a greater magnitude than signal **2**, a favorable comparison may be achieved when the magnitude of signal **1** is greater than that of signal **2** or when the magnitude of signal **2** is less than that of signal **1**. As may be used herein, the term "compares unfavorably", indicates that a comparison between two or more items, signals, etc., fails to provide the desired relationship.

As may also be used herein, the terms "processing module", "processing circuit", "processor", and/or "processing unit" may be a single processing device or a plurality of processing devices. Such a processing device may be a microprocessor, micro-controller, digital signal processor, microcomputer, central processing unit, field programmable gate array, programmable logic device, state machine, logic circuitry, analog circuitry, digital circuitry, and/or any device that manipulates signals (analog and/or digital) based on hard coding of the circuitry and/or operational instructions. The processing module, module, processing circuit, and/or processing unit may be, or further include, memory and/or an integrated memory element, which may be a single memory device, a plurality of memory devices, and/or embedded circuitry of another processing module, module, processing circuit, and/or processing unit. Such a memory device may be a read-only memory, random access memory, volatile memory, non-volatile memory, static memory, dynamic memory, flash memory, cache memory, and/or any device that stores digital information. Note that if the processing module, module, processing circuit, and/or processing unit includes more than one processing device, the processing devices may be centrally located (e.g., directly coupled together via a wired and/or wireless bus structure) or may be distributedly located (e.g., cloud computing via indirect coupling via a local area network and/or a wide area network). Further note that if the processing module, module, processing circuit, and/or processing unit implements one or more of its functions via a state machine, analog circuitry, digital circuitry, and/or logic circuitry, the memory and/or memory element storing the corresponding operational instructions may be embedded within, or external to, the circuitry comprising the state machine, analog circuitry, digital circuitry, and/or logic circuitry. Still further note that, the memory element may store, and the processing module, module, processing circuit, and/or processing unit executes, hard coded and/or operational instructions corresponding to

at least some of the steps and/or functions illustrated in one or more of the Figures. Such a memory device or memory element can be included in an article of manufacture.

One or more embodiments have been described above with the aid of method steps illustrating the performance of specified functions and relationships thereof. The boundaries and sequence of these functional building blocks and method steps have been arbitrarily defined herein for convenience of description. Alternate boundaries and sequences can be defined so long as the specified functions and relationships are appropriately performed. Any such alternate boundaries or sequences are thus within the scope and spirit of the claims. Further, the boundaries of these functional building blocks have been arbitrarily defined for convenience of description. Alternate boundaries could be defined as long as the certain significant functions are appropriately performed. Similarly, flow diagram blocks may also have been arbitrarily defined herein to illustrate certain significant functionality.

To the extent used, the flow diagram block boundaries and sequence could have been defined otherwise and still perform the certain significant functionality. Such alternate definitions of both functional building blocks and flow diagram blocks and sequences are thus within the scope and spirit of the claims. One of average skill in the art will also recognize that the functional building blocks, and other illustrative blocks, modules and components herein, can be implemented as illustrated or by discrete components, application specific integrated circuits, processors executing appropriate software and the like or any combination thereof.

In addition, a flow diagram may include a "start" and/or "continue" indication. The "start" and "continue" indications reflect that the steps presented can optionally be incorporated in or otherwise used in conjunction with other routines. In this context, "start" indicates the beginning of the first step presented and may be preceded by other activities not specifically shown. Further, the "continue" indication reflects that the steps presented may be performed multiple times and/or may be succeeded by other activities not specifically shown. Further, while a flow diagram indicates a particular ordering of steps, other orderings are likewise possible provided that the principles of causality are maintained.

The one or more embodiments are used herein to illustrate one or more aspects, one or more features, one or more concepts, and/or one or more examples. A physical embodiment of an apparatus, an article of manufacture, a machine, and/or of a process may include one or more of the aspects, features, concepts, examples, etc. described with reference to one or more of the embodiments discussed herein. Further, from figure to figure, the embodiments may incorporate the same or similarly named functions, steps, modules, etc. that may use the same or different reference numbers and, as such, the functions, steps, modules, etc. may be the same or similar functions, steps, modules, etc. or different ones.

Unless specifically stated to the contra, signals to, from, and/or between elements in a figure of any of the figures presented herein may be analog or digital, continuous time or discrete time, and single-ended or differential. For instance, if a signal path is shown as a single-ended path, it also represents a differential signal path. Similarly, if a signal path is shown as a differential path, it also represents a single-ended signal path. While one or more particular architectures are described herein, other architectures can likewise be implemented that use one or more data buses not expressly shown, direct connectivity between elements, and/or indirect coupling between other elements as recognized by one of average skill in the art.

The term "module" is used in the description of one or more of the embodiments. A module implements one or more functions via a device such as a processor or other processing device or other hardware that may include or operate in association with a memory that stores operational instructions. A module may operate independently and/or in conjunction with software and/or firmware. As also used herein, a module may contain one or more sub-modules, each of which may be one or more modules.

As may further be used herein, a computer readable memory includes one or more memory elements. A memory element may be a separate memory device, multiple memory devices, or a set of memory locations within a memory device. Such a memory device may be a read-only memory, random access memory, volatile memory, non-volatile memory, static memory, dynamic memory, flash memory, cache memory, and/or any device that stores digital information. The memory device may be in a form a solid state memory, a hard drive memory, cloud memory, thumb drive, server memory, computing device memory, and/or other physical medium for storing digital information.

While particular combinations of various functions and features of the one or more embodiments have been expressly described herein, other combinations of these features and functions are likewise possible. The present disclosure is not limited by the particular examples disclosed herein and expressly incorporates these other combinations.

What is claimed is:

1. A method for execution by one or more processing modules of one or more computing devices of a distributed storage network (DSN), the method comprises:

identifying an encoded data slice to be rebuilt within a distributed storage (DS) unit;

obtaining status information of the DS unit;

selecting a rebuilding approach based on the status information, the rebuilding approach including an internal approach or an external approach, where the internal approach and the external approach are both available based on the status information;

obtaining, upon selecting the internal approach, internal rebuilding information from one or more memories of the DS unit, wherein the internal rebuilding information includes a decode threshold number of rebuilding elements; and

rebuilding the encoded data slice to be rebuilt utilizing the internal rebuilding information, wherein the threshold number of rebuilding elements includes at least a decode threshold number of internal memories of a plurality of internal memories within the DS unit;

obtaining, upon selecting the external approach, external rebuilding information from at least a decode threshold number of other DS units of a set of DS units that includes the DS unit; and

rebuilding the encoded data slice to be rebuilt utilizing the external rebuilding information.

2. The method of claim **1**, wherein the identifying includes at least one of: receiving an error message, comparing storage integrity information to calculated integrity information, or comparing a slice name list from the DS unit and from other DS units of a DS unit set that includes the DS unit.

3. The method of claim **1**, wherein the status information includes one or more of: a network traffic level, a number of available other DS units of the set of DS units, estimated

network traffic costs, a loading level of the DS unit, available resources of the DS unit, or active operation types of the DS unit.

4. The method of claim **1**, wherein the threshold number includes at least one of: a threshold number of encoded data slices of a set of encoded data slices when a dispersed storage error coding function is utilized or a threshold number of data blocks or parity blocks when a redundant array of independent disks (RAID) function is utilized.

5. The method of claim **4**, wherein the internal rebuilding information includes retrieving the threshold number of data blocks and parity blocks from a threshold number of the internal memories of the DS unit when the redundant array of independent disks (RAID) function is utilized.

6. The method of claim **1**, wherein the internal rebuilding information further includes retrieving the threshold number of encoded data slices from a threshold number of the internal memories of the DS unit when a dispersed storage error coding function is utilized.

7. The method of claim **1**, wherein the external approach includes utilizing the external rebuilding information for at least the threshold number of other DS units of the set of DS units, where data is encoded using a dispersed storage error coding function to produce a set of encoded data slices, including the encoded data slice to be rebuilt, that are stored in the set of DS units.

8. The method of claim **7**, wherein the rebuilding includes decoding a retrieved threshold number of encoded data slices using a dispersed storage error coding function to produce a rebuilt slice.

9. The method of claim **1** further comprises determining a storage approach for the DS unit based on one or more of receiving the storage approach, a lookup, or selecting the storage approach based on storage requirements when initially storing data.

10. The method of claim **1**, wherein the rebuilding the encoded data slice to be rebuilt utilizing the internal rebuilding information includes utilizing a RAID function on the threshold number of data blocks and parity blocks to produce the rebuilt encoded data slice.

11. The method of claim **1**, wherein the obtain external rebuilding information includes issuing at least a decode threshold number of reads slice requests to other DS units and receiving at least a decode threshold number of read slice responses.

12. The method of claim **11**, wherein the rebuildng the encoded data slice to be rebuilt utilizing the external rebuilding information includes decoding at least a decode threshold number of encoded data slices from the at least a decode threshold number of received read slice responses to produce the encoded data slice to be rebuilt.

13. A computing device of a group of computing devices of a distributed storage network (DSN), the computing device comprises:

an interface;

a local memory; and

a processing module operably coupled to the interface and the local memory, wherein the processing module functions to:

identify an encoded data slice to be rebuilt within a distributed storage (DS) unit;

obtain status information of the DS unit;

select a rebuilding approach based on the status information, the rebuilding approach including an internal approach or an external approach, where the internal approach and the external approach are both available based on the status information;

obtain, upon selecting the internal approach, internal rebuilding information from one or more memories of the DS unit, wherein the internal rebuilding information includes a threshold number of rebuilding elements; and

rebuild the encoded data slice to be rebuilt utilizing the internal rebuilding information wherein the threshold number of rebuilding elements includes at least a decode threshold number of internal memories of a plurality of internal memories within the DS unit;

obtain, upon selecting the external approach, external rebuilding information from at least a decode threshold number of other DS units of a set of DS units that includes the DS unit; and

rebuild the encoded data slice to be rebuilt utilizing the external rebuilding information.

14. The computing device of claim **13**, wherein the status information includes one or more of: a network traffic level, a number of available other DS units of the set of DS units, estimated network traffic costs, a loading level of the DS unit, available resources of the DS unit, or active operation types of the DS unit.

15. The computing device of claim **13**, wherein the external approach includes utilizing the external rebuilding information for at least a threshold number of other DS units of the set of DS units, where data is encoded using a dispersed storage error coding function to produce a set of encoded data slices, including the encoded data slice to be rebuilt, that are stored in the set of DS units.

16. The computing device of claim **13**, wherein the threshold number includes at least one of: a threshold number of encoded data slices of a set of encoded data slices when a dispersed storage error coding function is utilized or a threshold number of data blocks and parity blocks when a redundant array of independent disks (RAID) function is utilized.

17. The computing device of claim **13**, wherein the obtain external rebuilding information includes issuing at least a decode threshold number of reads slice requests to other DS units and receiving at least a decode threshold number of read slice responses.

18. A system comprises:

an interface;

a local memory; and

a processing module operably coupled to the interface and the local memory, wherein the processing module functions to:

identify an encoded data slice to be rebuilt within a distributed storage (DS) unit;

obtain status information of the DS unit;

select a rebuilding approach based on the status information, the rebuilding approach including an internal approach or an external approach, where the internal approach and the external approach are both available based on the status information;

obtain, upon selecting the internal approach, internal rebuilding information from one or more memories of the DS unit, wherein the internal rebuilding information includes a threshold number of rebuilding elements; and

rebuild the encoded data slice to be rebuilt utilizing the internal rebuilding information wherein the threshold number of rebuilding elements includes at least a decode threshold number of internal memories of a plurality of internal memories within the DS unit;

obtain, upon selecting the external approach, external rebuilding information from at least a decode threshold number of other DS units of a set of DS units that includes the DS unit; and

rebuild the encoded data slice to be rebuilt utilizing the external rebuilding information.

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